



UNIVERSITI PUTRA MALAYSIA

**EFFECTS OF AMBIENT TROPOSPHERIC OZONE ON MR-219 RICE
IN THE MUDA IRRIGATION SCHEME AREA**

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FPAS 2005 6

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By

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**Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia,
in Fulfilment of the Requirements for the Degree of Doctor of Philosophy**

April 2005



Abstract of thesis presented to the Senate of Universiti Putra Malaysia in fulfilment
of the requirement for the degree of Doctor of Philosophy

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June 2005

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Rice, the most important crop in Malaysia contributes about one-third of daily calorie intake among Malaysians, and it is the primary source of carbohydrates. As in many other developing countries in Asia, food security has been an integral national policy objective in Malaysia's development pursuits since the 1950s. The focus of the self-sufficiency programme has been on rice, as it is the staple food for the vast majority of the population. Domestic consumption of rice is projected to increase with increase in population; whereby the increase in production has to come from higher productivity in the existing granary areas since there is no plan to increase the area under paddy cultivation.

It has long been recognized that pollutant gases cause significant impacts on crops and forests in both developed and developing countries. Tropospheric ozone (O_3) is recognised as the pollutant most likely to cause widespread crop damage. For this pollutant an AOT40 (accumulative O_3 concentration above a threshold of 40 ppb) value causing 5% yield loss for all agricultural crops has been established as 3000 ppb·h, which is applicable during daylight hours over a growing season (UN-ECE, 1996). Comparatively, very few studies of tropospheric ozone impact on vegetation have been conducted in developing countries; majority of which; located along the

equatorial belt. This is a serious omission because of the greater importance of this issue in developing countries due to increasing demand for higher crop production in the face of growing populations, rapid deterioration of ambient air quality associated with industrialisation and urbanisation as well as land constraints. Moreover, Malaysia, which is located at the equatorial region, may be at an even greater risk because the climate that is characterised by high temperature and high levels of solar radiation, promote the formation of photochemical pollutants such as O₃.

For the above purpose, there is a pressing need to determine the actual air pollution impacts on vegetation especially rice plant, which is the main staple food of Malaysia. Forecasting crop yield well before harvest is crucial to enable planners and decision makers to predict how much to import in case of shortfall or optionally, to export in case of surplus. It also enables governments to put in place strategic contingency plans for redistribution of food during times of famine. Therefore, monitoring of crop development and of crop growth, and early yield prediction is very crucial. In order to have a complete estimate of air pollution damage i.e., O₃ to paddy plantation area, a dose-response, or yield-loss function have to be developed. In this study, data was gathered from tests in open-top chambers (OTCs), whereby four OTCs were fabricated; two of which were exposed to ambient air pollution (NF) of which ozone is the major perpetrator whilst the remaining were provided with clean air i.e. charcoal filtered air treatment (F). The response of a popular local rice cultivar, MR-219 to current ambient air pollution of which O₃ is the overwhelming dominant pollutant was investigated for five successive seasons in Muda Irrigation Scheme Area (MADA); the largest and imperative rice growing area in Malaysia. This method has been widely employed to assess crop yield responses to ozone.

The results of the study clearly indicate that at ozone concentrations even lower than the Malaysian air quality guidelines (60 ppb 8 hr mean) level, there exist a significant impact on the growth and yield of the popular rice cultivar MR-219. Even though weeds, diseases, and insect pests were absent, water and nutrients were in abundance, no adverse soil conditions, and that no extreme weather event such as

typhoons occurs; the physiological, growth and development performances of rice plants exposed to ambient ozone were found to be significantly ($P < 0.05$) reduced by AOT40 compared to control rice plants in filtered chamber. This study discovered that the root was the most significantly affected component of MR-219 rice plant. Meanwhile, reproductive stage is the most vulnerable period of growth to ozone impact followed by grain filling and vegetative stages, respectively. For plant growth and development study, yield is the most critical parameter. Statistically, a square root-Y equation epitomize the best fitting compared to other curvilinear models in describing yield reduction of rice plant due to ambient O_3 stress (DWF_G); represented by the following equation: $DWF_G = [9.636 - (0.0000303 * AOT40)]^2$. This study finding is undeniable imperative and it bestows the first algorithmic yield-loss model of crop to ozone in this country, ever.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan ijazah Doktor Falsafah

KESAN OZON TROPOSPERIK UDARA KASA KE ATAS PADI MR-219 DI KAWASAN SKIM PENGAIRAN MUDA

Oleh

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April 2005

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Beras adalah makanan ruji utama di Malaysia; di mana ianya membekalkan satu pertiga kalori bagi rakyat Malaysia dan juga merupakan sumber utama karbohidrat di negara ini. Sama seperti kebanyakan negara membangun yang lain di Asia, isu keselamatan makanan adalah sebahagian daripada agenda penting di dalam aspek pembangunan Negara Malaysia semenjak ianya mencapai kemerdekaan pada lewat 1950an. Tumpuan program sara diri ini adalah kepada penanaman padi memandangkan ianya adalah makanan ruji kebanyakan warga Malaysia. Pengambilan domestik beras negara diramalkan akan meningkat sejajar dengan peningkatan penduduk, namun peningkatan ini perlu datang dari kawasan penanaman padi sedia ada memandangkan tiadanya rancangan perluasan kawasan penanaman padi oleh pihak penggubal dasar negara.

Pencemar udara yang mana ozon troposperik adalah bahan utamanya, telah lama dikenalpasti memberi impak yang signifikan terhadap tumbuhan tanaman dan hutan di negara maju maupun di negara yang sedang membangun. Bagi ozon troposperik (O_3) ini, AOT40 (kumulatif kepekatan O_3 melebihi had 40 bahagian per billion) yang mengakibatkan 5% pengurangan hasil bagi semua tanaman pertanian telah diwujudkan, iaitu sebanyak 3000 ppb h, relevan bagi jam diwaktu siang yang dilimpahi cahaya matahari, untuk suatu musim tanaman (UN-ECE, 1996). Secara

perbandingan, amat sedikit kajian tentang kesan ozon troposfera ke atas tanaman yang telah dijalankan di negara membangun, yang mana kebanyakan negara-negara ini terletak di kawasan Khatulistiwa. Ini merupakan suatu pengabaian yang serius kerana isu ini adalah lebih kritikal dan mendesak di negara membangun. Negara-negara membangun secara amnya memerlukan hasil tanaman yang lebih tinggi akibat pertumbuhan kadar penduduk yang pesat, kualiti udara yang semakin merosot kesan daripada proses industrialisasi dan urbanisasi, disamping kekangan kawasan pertanian. Lebih membimbangkan lagi ialah disebabkan lokasi Malaysia yang terletak di Khatulistiwa, risiko kesan ozon troposfera ke atas tanaman adalah lebih tinggi. Ini kerana iklim tropika yang bercirikan suhu yang tinggi serta keamatan cahaya suria yang melimpah sepanjang tahun menggalakkan pembentukan ozon troposfera.

Sayugia itu, terdapatnya keperluan yang mendesak bagi penentuan secara kuantitatif kesan pencemar udara ke atas tanaman terutamanya padi, yang merupakan makanan asasi rakyat Malaysia. Ramalan secara saintifik jumlah hasil tanaman padi adalah sangat penting bagi membolehkan para pentadbir dan penggubal dasar negara menganggarkan jumlah yang perlu diimpot sekiranya terdapat kekurangan pengeluaran ataupun andaikata berlebihan, mengeksportkannya. Ini membolehkan kerajaan melaksanakan pelan kecemasan bagi pembahagian makanan semasa kejadian bencana. Oleh itu, pemantauan pertumbuhan dan perkembangan tanaman serta ramalan awal jumlah hasil tanaman adalah amat penting. Bagi mendapatkan anggaran tepat tentang kesan ozon troposfera ke atas kawasan penanaman padi, suatu dos-respon, atau dikenali juga sebagai fungsi kehilangan hasil perlu diwujudkan. Dalam kajian ini, data-data dikumpulkan dari ujikaji yang dijalankan didalam kebuk terbuka di atas (open top chamber). Empat unit kebuk atas terbuka telah dibina; dua unit dibekalkan dengan udara kasa(NF) dimana ozon troposfera merupakan bahan pencemar utama; sementara dua unit lagi mendapat udara bersih yang ditapis menggunakan penapis arang (F). Kaedah ini digunakan secara meluas bagi mengetahui tindakbalas ozon ke atas tanaman. Kajian ini dijalankan selama lima musim berturut-turut di Kawasan Skim Pengairan Muda (MADA) yang

merupakan kawasan penanaman terpenting di Malaysia, melibatkan jenis padi tempatan yang amat popular, iaitu kultivar MR-219.

Keputusan kajian ini jelas menunjukkan bahawa walaupun pada kepekatan ozon troposfera yang lebih rendah daripada Garispanduan Kualiti Udara Malaysia (60 ppb 8 jam purata), terdapatnya kesan yang signifikan terhadap tumbesaran dan hasilan pada padi MR-219. Walaupun tidak terdapatnya rumpai, penyakit serta serangga perosak, air dan nutrien yang mencukupi, tanah yang subur serta tiadanya bencana yang melanda; namun kadar tumbesaran pokok padi yang terdedah kepada ozon udara kasa mengalami pengurangan yang signifikan ($P < 0.05$) berbanding dengan pokok padi yang ditanam di dalam kebuk terbuka di atas (open top chamber). Kajian ini mendapati bahawa akar merupakan parameter yang paling teruk menerima kesan ozon udara kasa sementara peringkat pertumbuhan adalah peringkat yang paling terjejas diikuti peringkat pengisian bijirin. Bagi kajian tumbesaran tanaman, hasilan merupakan parameter yang paling kritikal. Secara statistiknya, algoritma punca kuasdua adalah persamaan yang paling tepat bagi menggambarkan dos-respon pengurangan hasilan padi kesan ozon udara kasa iaitu: $DWF_G = [9.636 - (0.0000303 * AOT40)]^2$. Tidak dapat disangkal lagi, hasil kajian ini adalah amat penting dan ianya telah mengwujudkan model algoritma dos-respon pengurangan hasilan padi kesan ozon udara kasa yang pertama bagi Malaysia.

ACKNOWLEDGEMENT

*In the name of ALLAH, the Merciful, the Compassionate.
Praise be to God, Lord of the Universe, The Gracious, the Merciful.
Amin.*

Al-Qur'an, 1:1-3.

First and foremost, I would like to express my heartfelt thanks and appreciation to my supervisory committee chairman, Assoc. Prof. Dr. Ahmad Makmom Abdullah for his advice, guidance, constructive criticisms, valuable suggestions and most of all, for his kindness, throughout this study.

My deepest gratitude also to the members of my supervisory committee, Assoc. Prof. Dr. Wan Nor Azmin Sulaiman, Assoc. Prof. Dr. Mohd. Kamil Yusoff and Assoc. Prof. Dr. Azizi Muda without whose help, this project would never achieve success. Their contribution and numerous critical comments are profoundly appreciated.

Special note of gratitude and sincere thanks to Mohd. Asimi, Shamsuddin and Sharifah Azlina for their assistance all through this study.

Ultimately, no single phrase or expression can adequately reflect my gratefulness and love to my family, above all Saïen Muzalifah Ismail, Hajjah Amnah Hj. Salleh, Hajjah Hasnah Abd. Hamid and Haji Ismail Rahmad for their moral support, sacrifices, inspiration and understanding.

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I certify that an Examination Committee met on 19th April 2005 to conduct the final examination of Marzuki Haji Ismail on his Doctor of Philosophy thesis entitled "The Effect of Ambient Tropospheric Ozone on MR-219 Rice in the Muda Irrigation Scheme Area" in accordance with Universiti Pertanian Malaysia (Higher Degree) Act 1980 and Universiti Pertanian Malaysia (Higher Degree) Regulations 1981. The Committee recommends that the candidate be awarded the relevant degree. Members of the Examination Committee are as follows:

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DECLARATION

I hereby declare that the thesis is based on my original work except for quotations and citations that have been duly acknowledged. I also declare that it has not been previously or concurrently submitted for any other degree at Universiti Putra Malaysia (UPM) or any other institution.



MARZUKI HJ. ISMAIL

Date: 14 / 4 / 2005

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LIST OF ABBREVIATION

$*$	-	Multiply
α	-	Light utilization efficiency
ε	-	Initial light use efficiency
θ	-	Convexity
A_{\max}	-	Maximum assimilation rate
AFO	-	Area Farmer Organization
ANOVA	-	Analysis of variance
AOT40	-	Accumulative O ₃ concentration above a threshold of 40 part per billion
API	-	Air Pollution Index
°C	-	Degree Celsius
CO	-	Carbon monoxide
CO ₂	-	Carbon dioxide
DAP	-	Days after planting
DOE	-	Department of Environment
DRIS	-	Diagnosis and Recommendation Integrated System
DW	-	Dry weight of MR219 rice plant
E	-	Transpiration
EQA	-	Environmental Quality Act
f	-	Function of
G_s	-	Stomatal conductance
H ₂ O	-	Water
k	-	Extinction coefficient
LAI	-	Leaf area index
MADA	-	Muda Development Authority
MAQI	-	Malaysian Air Quality Index